Build Guide for Raspberry Pi Drone

Artifact for
Quantifying the Design-Space Tradeoffs in Autonomous Drones
ASPLOS 2021

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Overall Components And Their Functions

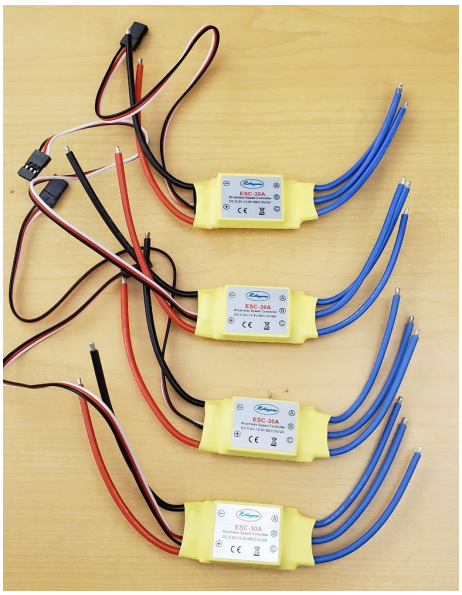
Step 1: Soldering the bullet connectors onto the ESCs

Components used: bullet connectors (in box of motor), ESCs

Parts needed: solder iron, solder, helping hands (recommended)

Bullet Connectors

Solder



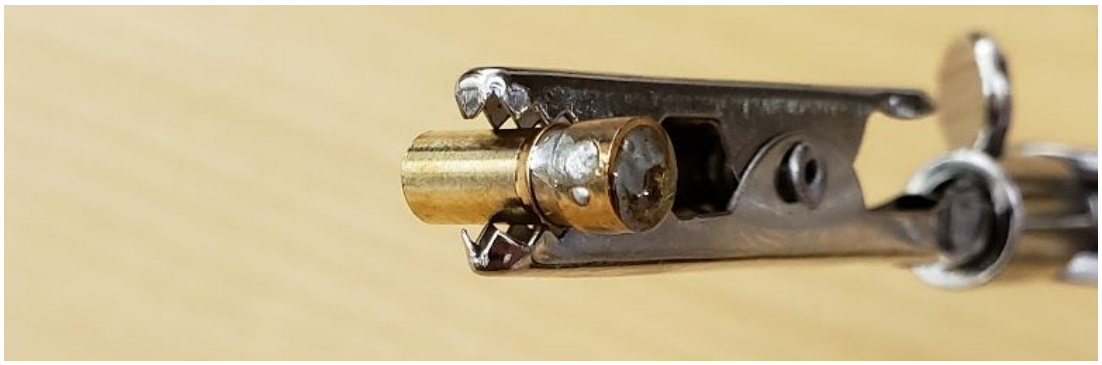
ESCs

Solder Iron

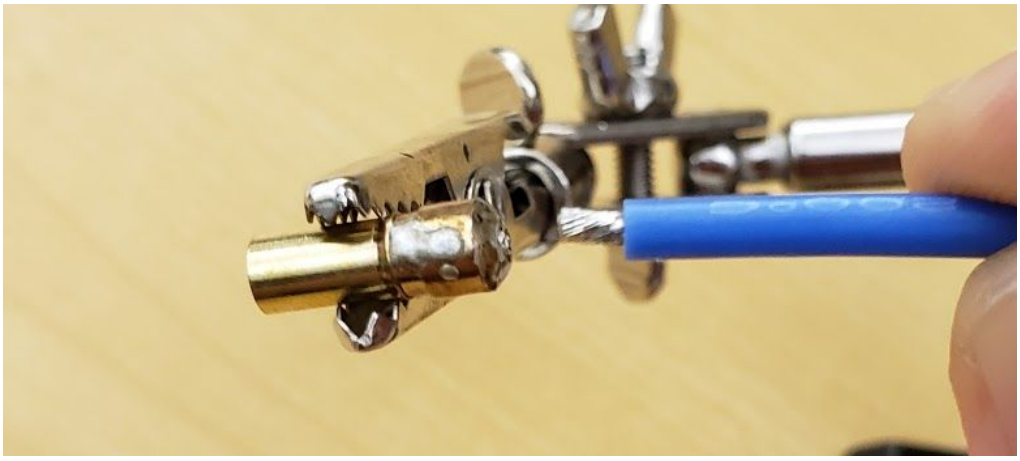
Helping Hands

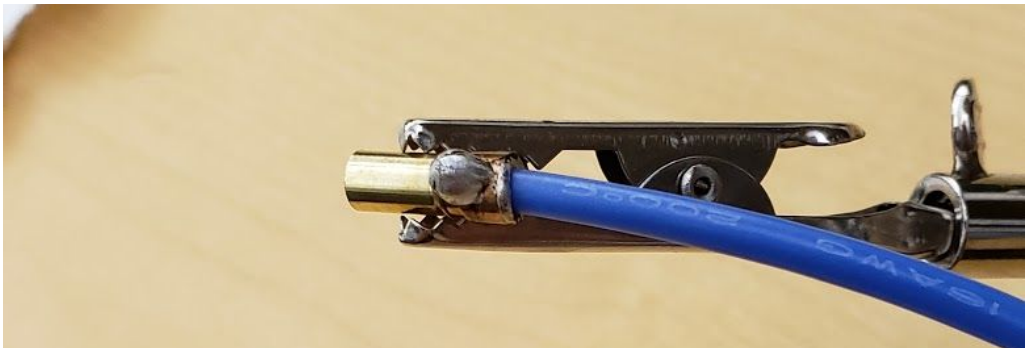
Process:

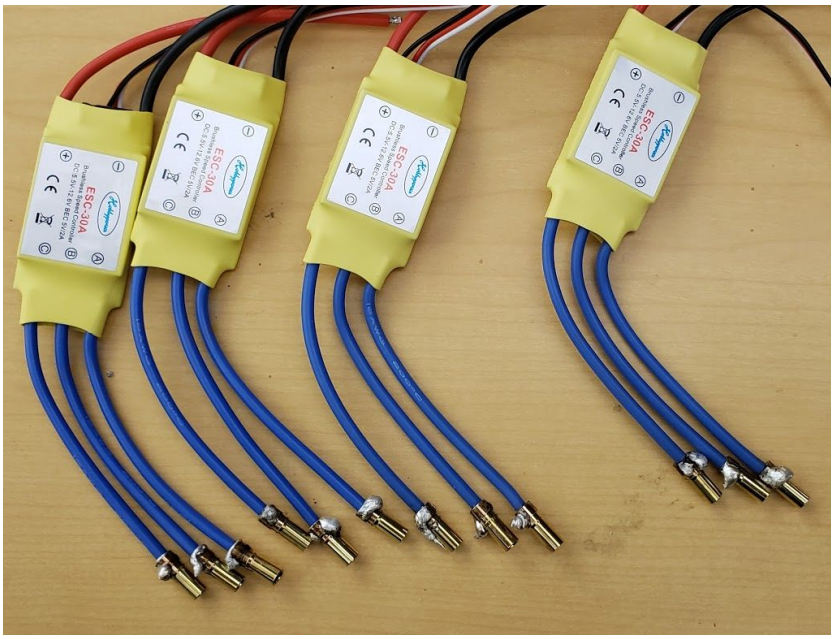
Put a bullet connector into the helping hands. We are going to fill the side with the hole with solder. See images:



Now, we are going to connect one of the “blue ends” of an ESC to the bullet connector. To do this, heat up the connector with the solder iron and when the solder is melted, push the connector inside and then let the solder solidify. Repeat this step for the remaining two “blue ends” of the ESC. Then repeat all these steps for the other 3 ESCs. In the end, you should have something looking like this:



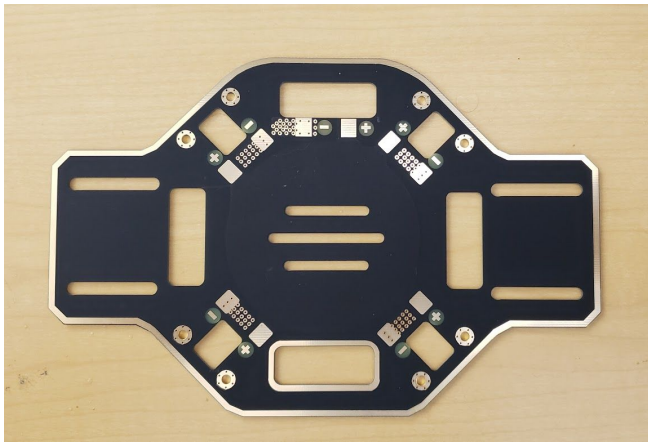




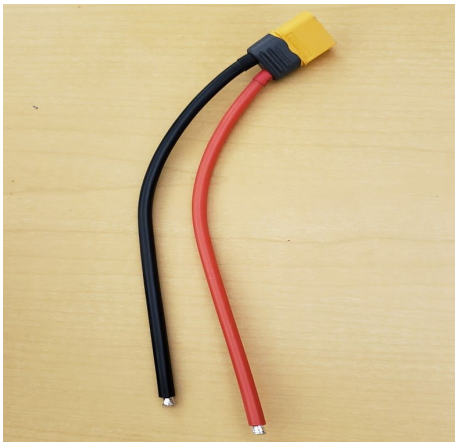
Step 2: Soldering the ESCs to the distribution board and soldering battery connector to board

Parts needed: soldering iron and solder

Components: bottom plate of board, ESCs, and battery connector



Bottom Plate

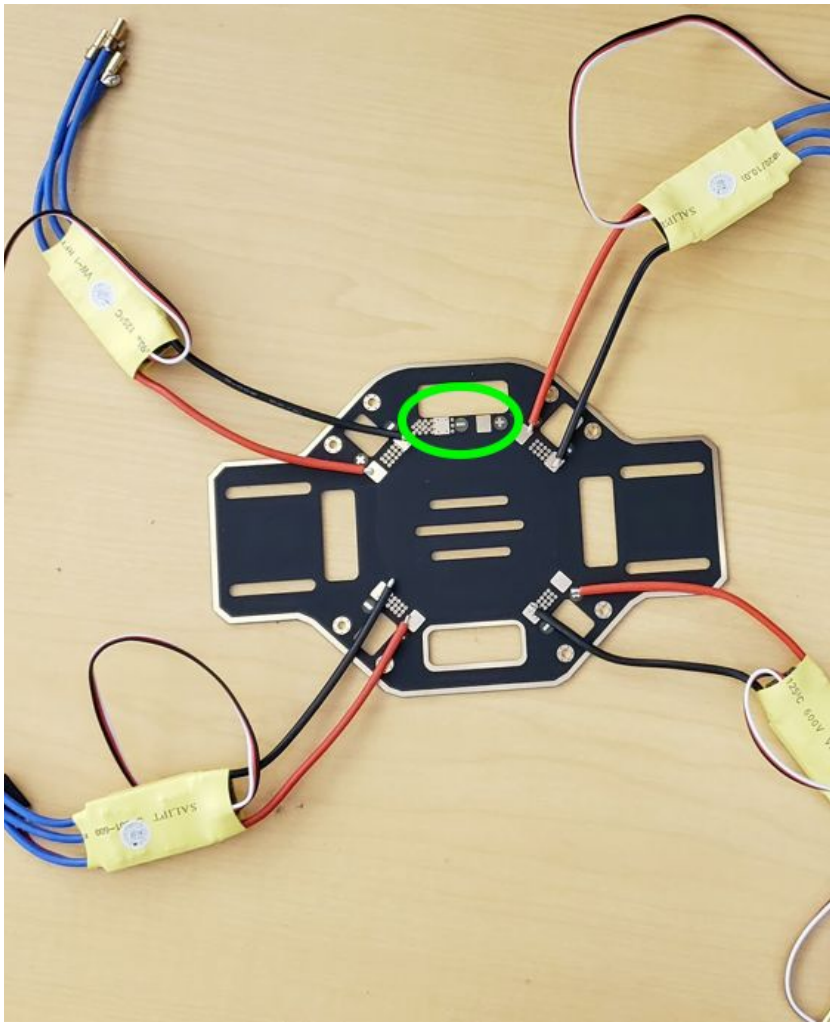


Battery Connector

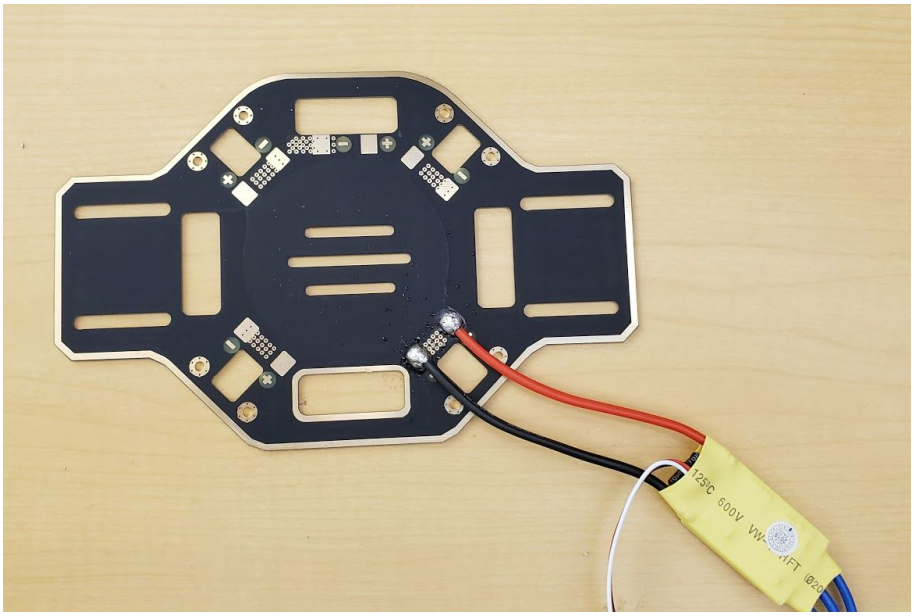
Process:

We need to connect the positive ESC wire (red wire) to the positive terminal on the board. The positive terminal has the + sign on it. We connect the negative wire (black wire) to the negative terminal on the PCB board. Please ensure your orientation is correct (see image below labeled ‘Orientation’). Basically, the logo on ESC should be faced down.

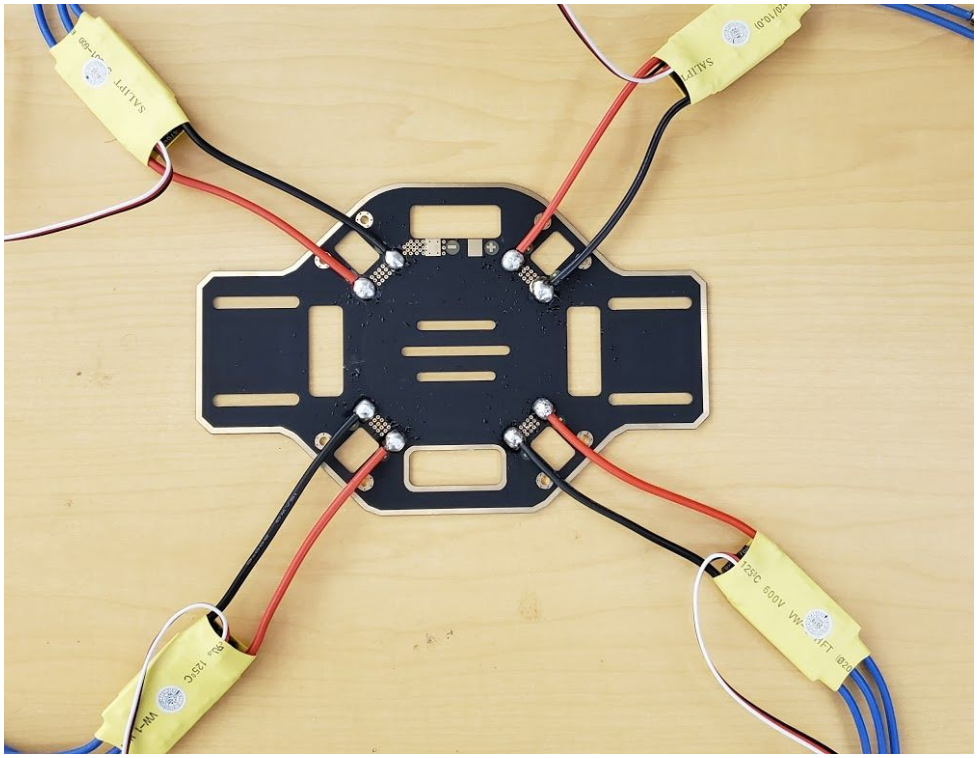
Note: The ESCs attach to the terminals which represent the X configuration. The extra terminal (circled green) is where we will attach the battery connector in a later stage.



Orientation

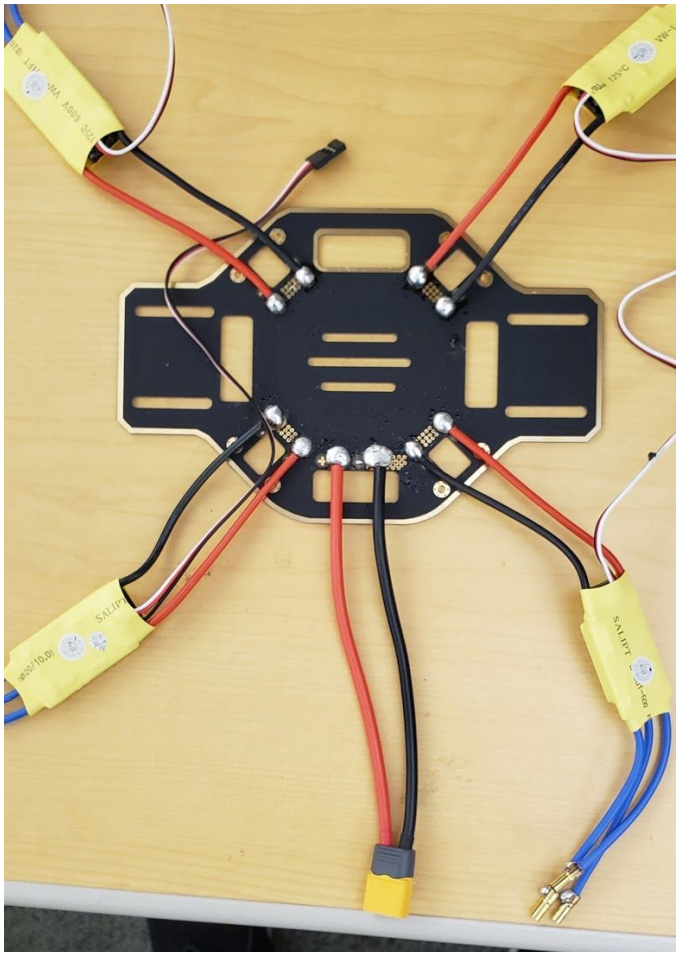


First Step



Second Step

Now solder the battery connector to the board. Solder the positive (red) wire to the + terminal on the board. Solder the negative (black) wire to the - terminal on the board. See image below:



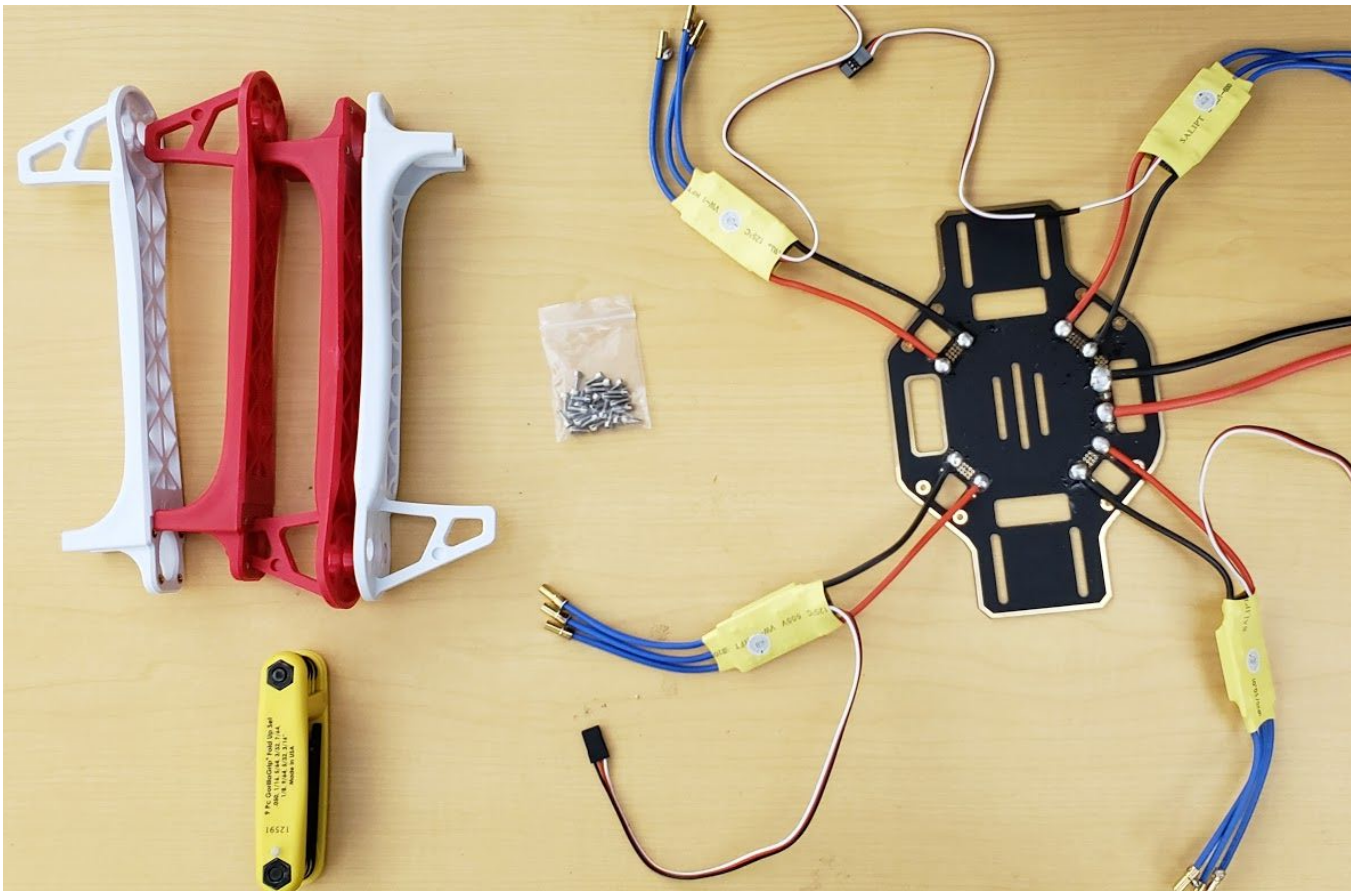
Please use a multimeter to ensure no short circuit has occurred while soldering. A short circuit that is not fixed right now can lead to rapid LiPo battery decomposition (explosion).

After verifying everything is OK, you can put away your solder iron since no more soldering is required in this project.

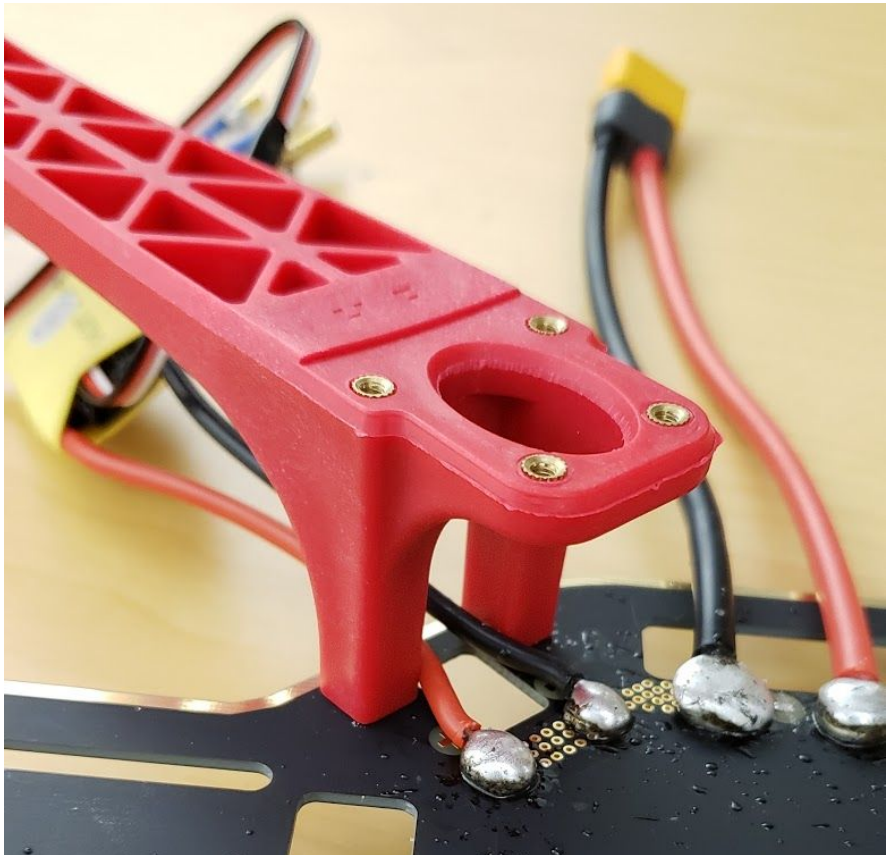
Step 3: Attaching drone arms to bottom plate

Parts needed: screws that came with frame (in the small bag in the image) and appropriate wrench

Components: bottom plate of board and arms (red and white components on the left in the image)

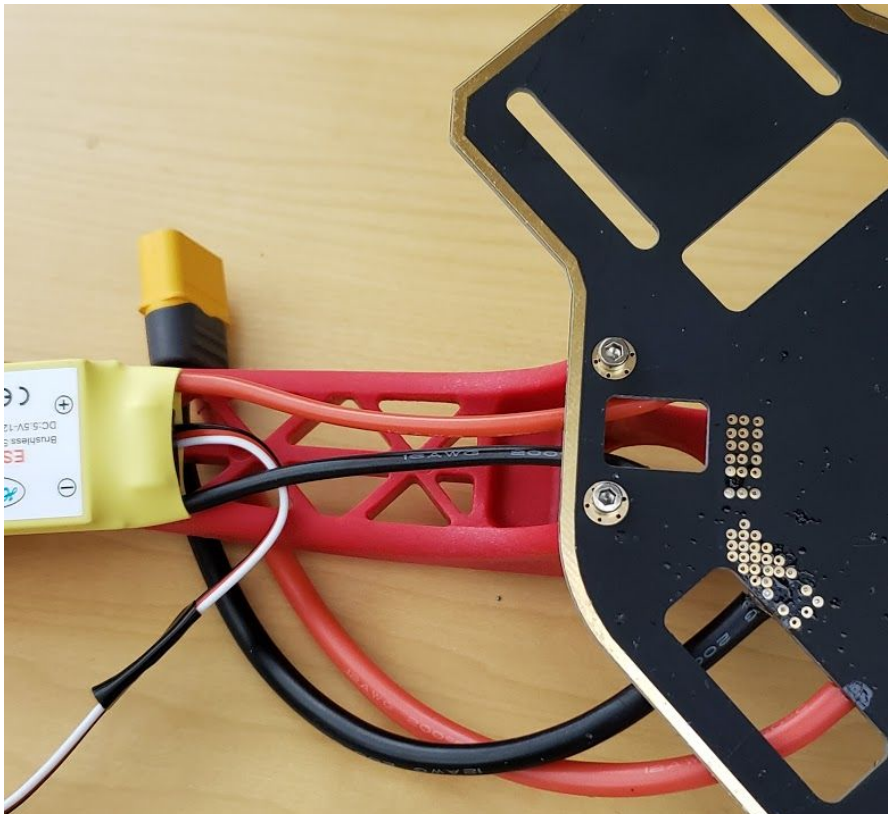


Step 3 Overview

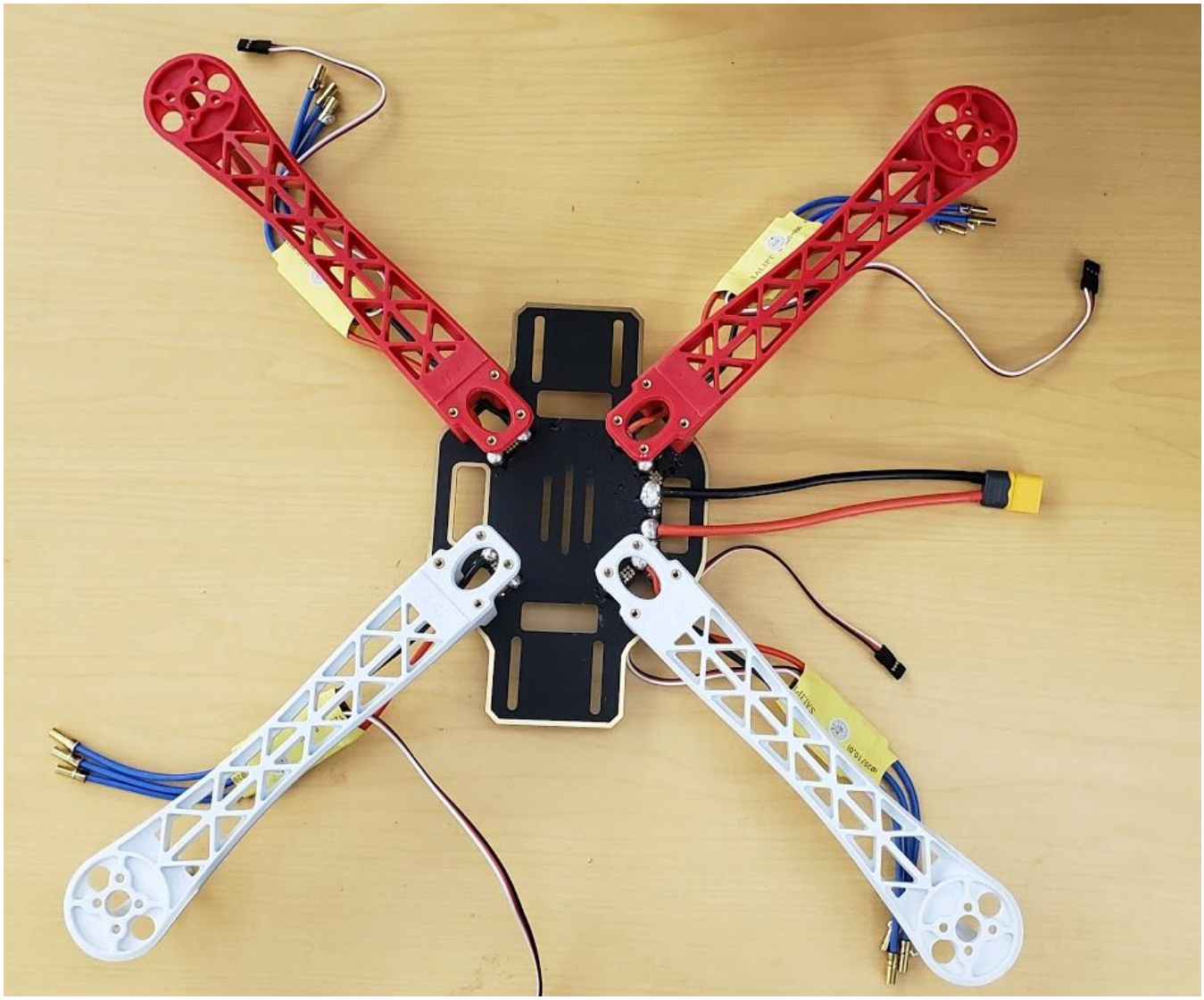


Process: use the screws to attach the arm to the frame. Try keeping the same color to one side to help you later on understand which way your drone is facing while flying. (see completed image of all arms below)

While screwing in the arm, put the wires of the ESC in between the gap created by the arm.



Once complete, do this for all four arms. It should look like this:



Result

Step 4: Installing motors onto the frame

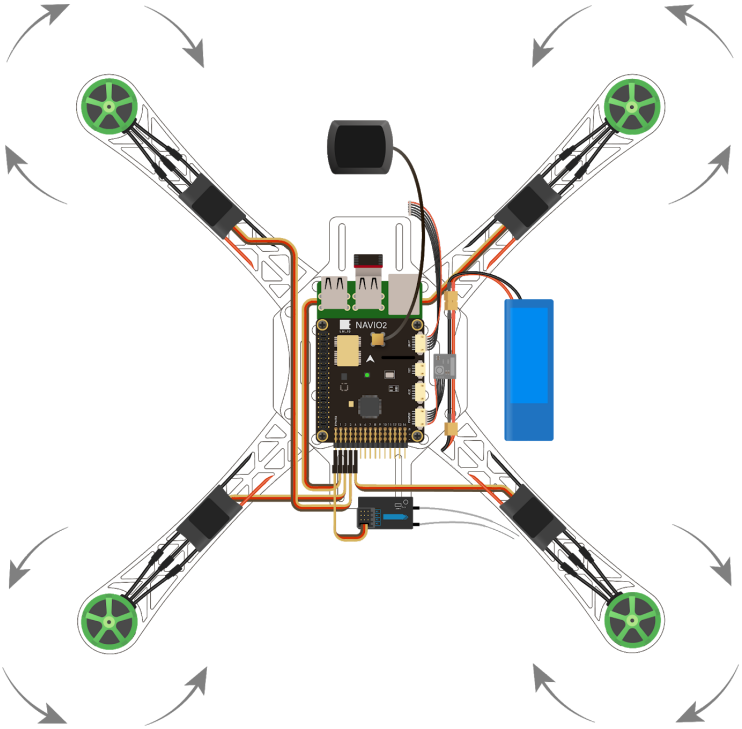
IMPORTANT: Before proceeding please understand the following:

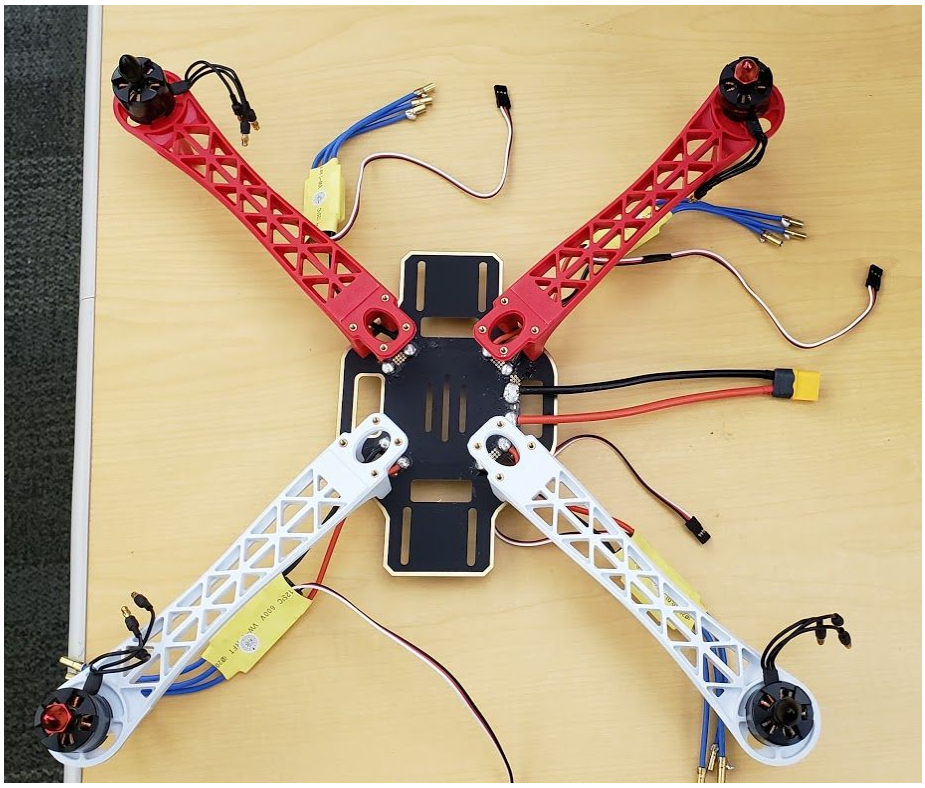
1) **Motors have specific spin direction**
2) **Spin direction is either Clockwise (CW) or CounterClockWise (CCW)**
3) **Red color top screw/nut means motor spins CCW**
4) **Black color top screw/nut means motor spins CW**
5) **INSTALLING MOTORS WRONG WILL CRASH YOUR DRONE**
6) **Incorrect color screw/nut will not tighten onto motor so that's how you know if you made a mistake**
7) **When you remove the motor from its box, the screw should be inside in one of those holes in the foam. Immediately take the screw and screw it onto the motor so that you don't confuse yourself with which motors spins CW and CCW**

Components: drone frame, motors, and long screws that came with the frame

Drone Frame, Motors, And Long Screws

DIAGRAM OF HOW TO ORIENT MOTORS:





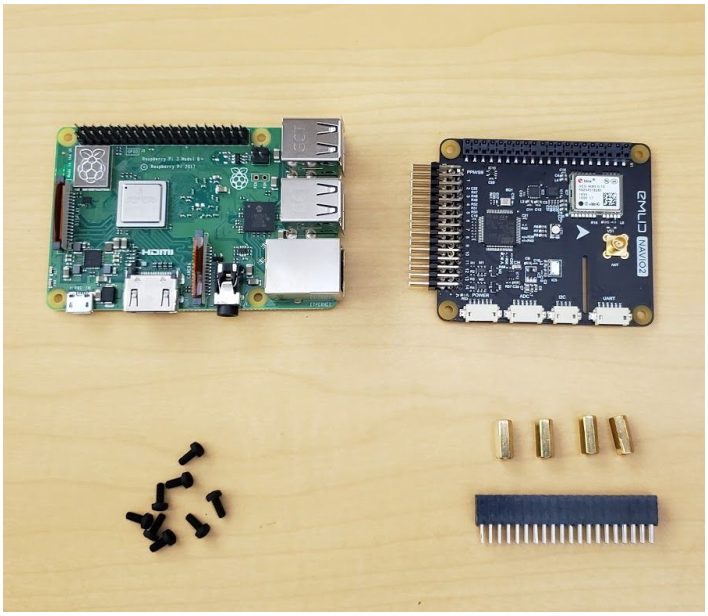
Process: Use the long screws to secure the motors to the frame. 4 screws per motor

Step 5: Install NAVIO2 HAT onto Raspberry Pi

Parts needed: screwdriver

Components: screws, pin header, and spacers that come in NAVIO box, Raspberry Pi, NAVIO2 HAT

Note: we are using Raspberry Pi 3 Model B+

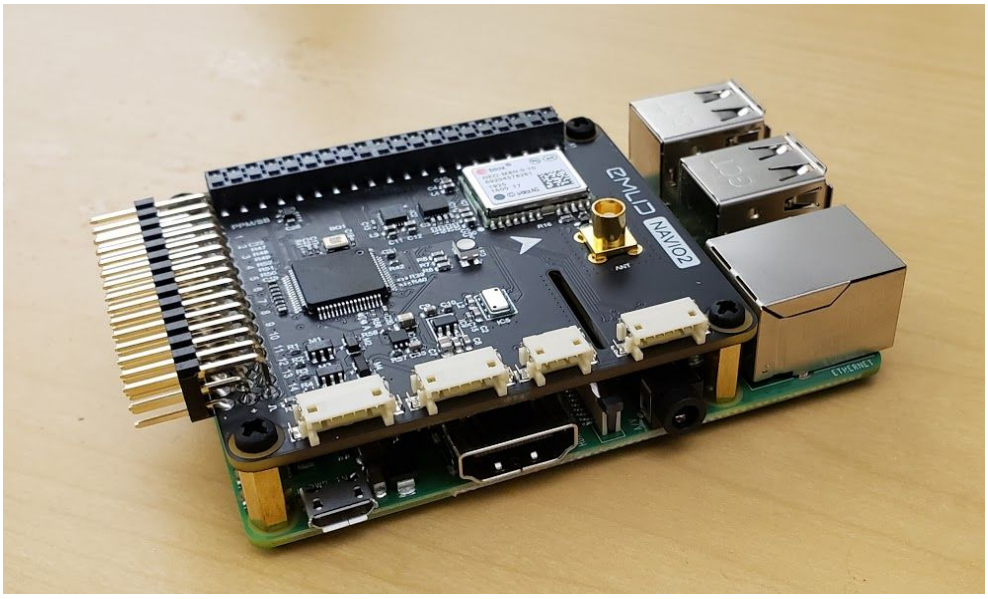


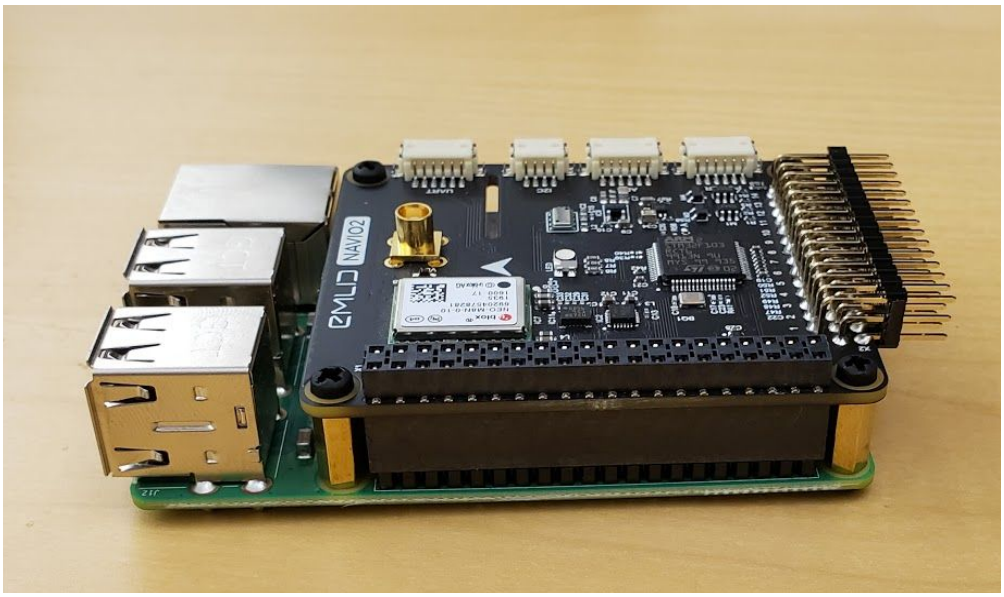
Components

Process:

First using 4 screws, install the standoffs onto the Pi and tighten screws. Then attach the pin header onto the Pi.
Then, attach and press down the NAVIO2 onto the Pi. Use the remaining 4 screws to secure the NAVIO2.

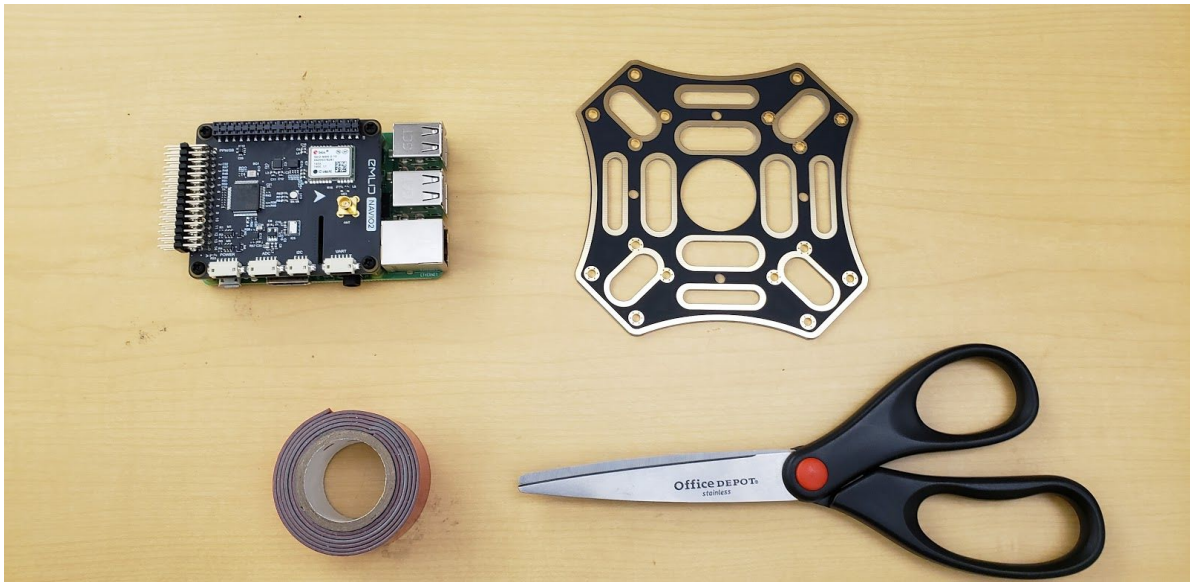
The entire completed setup will look like this:





Step 6: Install Pi+NAVIO2 onto the top plate

Components and parts needed: double sided tape, Pi+NAVIO2, top plate



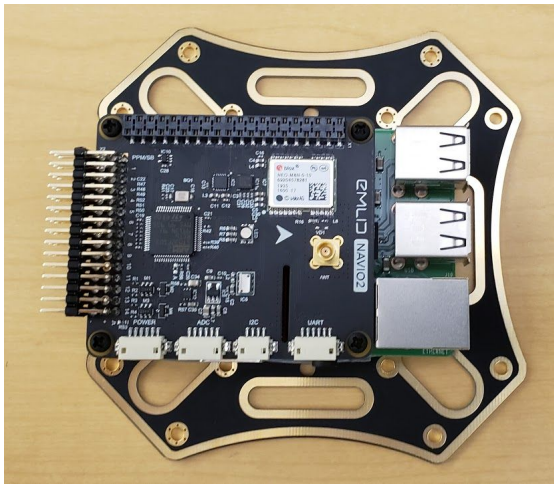
Process: Flip the Pi and place it on the table.

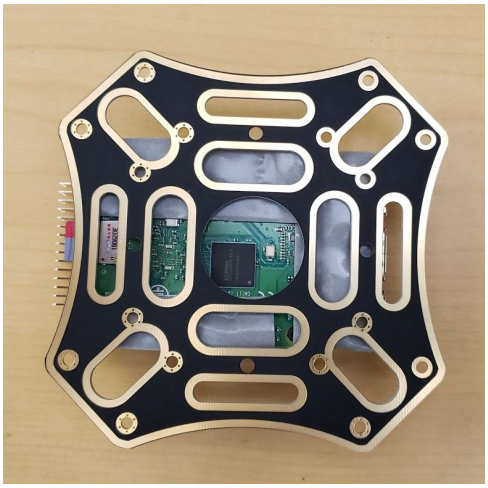
Put the double sided sticky tape on the Pi as shown. DO NOT COVER THE BLACK CHIP OR THE SD CARD SLOT!!!

Remove the red top cover to expose the sticky side of the tape.

Now we need to place this Pi onto the top plate.

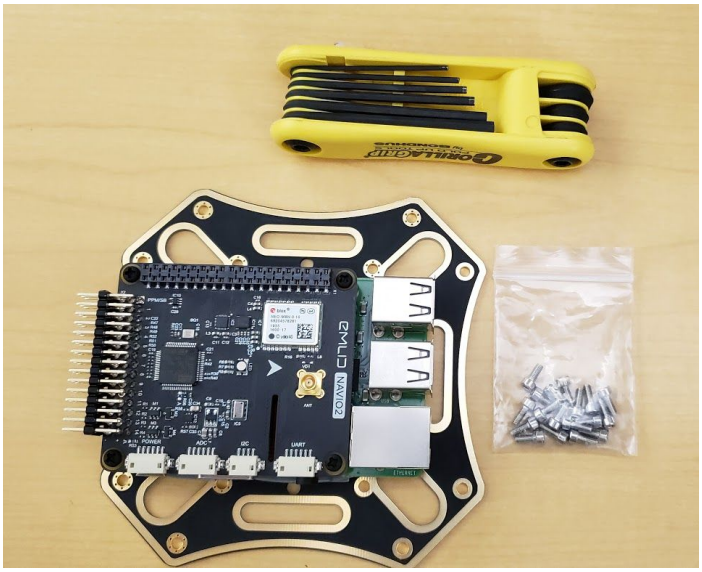
Place it almost in the center but slightly to the back to allow access to the SD card slot after the drone is built. See images below

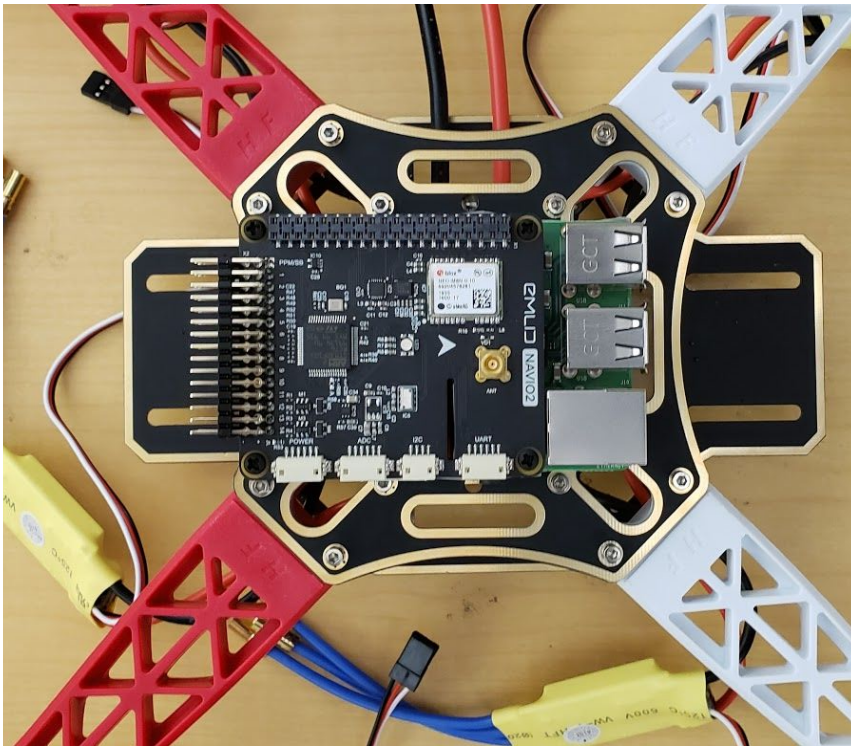




Step 7: Installing top plate to the drone

Parts and components needed: screws (that came with frame), top plate, wrench





Process: Attach the top plate to the drone using the screws. It is completely okay to only use 3 screws per corner. Don't worry about the 4th.

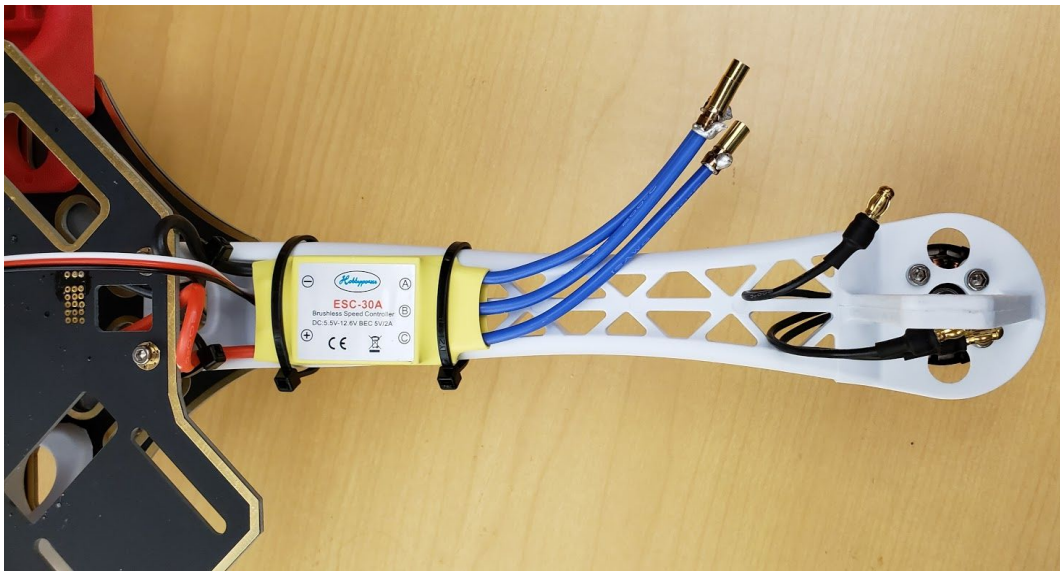
After doing that, the drone should look like this image on the left.

Step 8: Fixing ESCs to frame securely

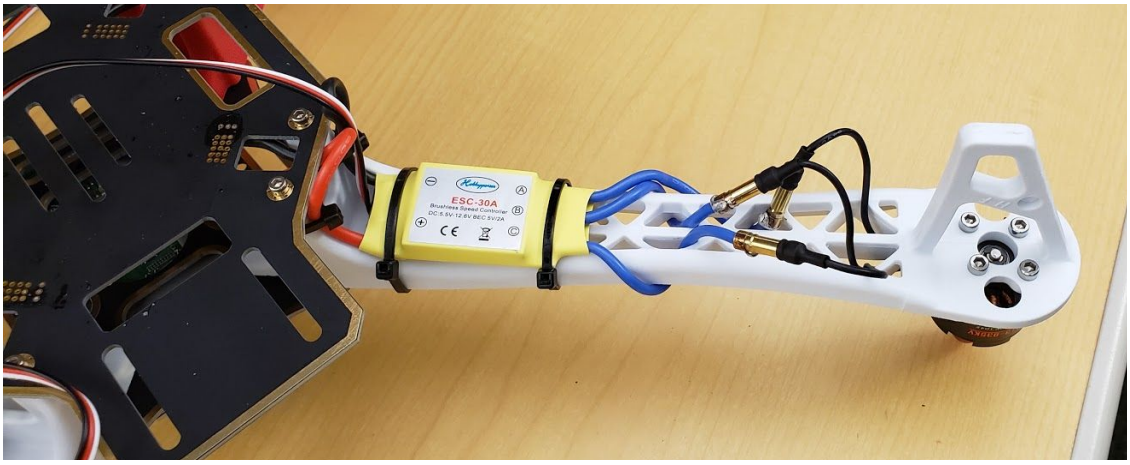
Components needed: drone, zip ties

Process: feed the motor wires through the frame so the wire leads are at the bottom near the bullet connectors. Then, zip tie the ESC to the frame, as close as possible to the frame. Also, zip tie the red and black wires of the ESC to aid in support.

This is what it should look like:



Now, loop the blue ESC wires to take away slack. Then, connect the bullet connectors to the motor leads. See image below. The order doesn't matter for now. Also, do not put any tape or heat shrink as later we may need to remove the connectors to fix spin direction.



Repeat these steps on all four arms of the drone.

Step 9: Bind Controller/Transceiver/Transmitter with the Receiver

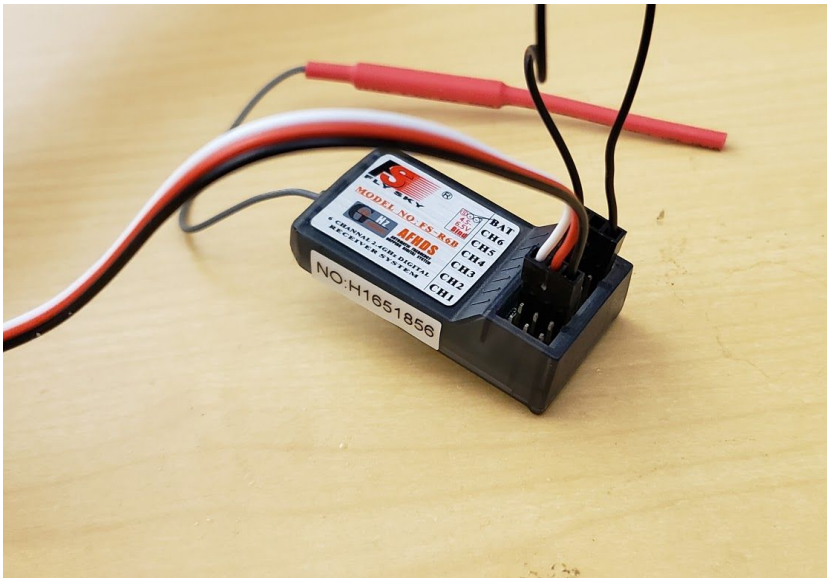
Components needed: RC controller/transmitter, RC receiver, jumper cable that came with receiver, battery converter, AA batteries for RC controller, charged drone battery

Process:

First, take the jumper cable and attach it to the BAT slot on the receiver (see image below)

Now, put 8 AA batteries into the RC Transmitter.

Pick any 1 ESC. Take its White-Red-Black wire and plug it into channel 3 on the receiver. The white wire should be closest to the receiver label and the black wire should be furthest away from the label. See image below:



Plug in the battery converter into the battery. Then plug in the battery into the drone power connector. The ESCs should start making beeping sounds and you should see a blinking red light inside the receiver.

A blinking red light indicates that that receiver and transmitter/controller haven't been binded/paired yet. So let's do that.

Make sure the controller is OFF.

Holding down the BIND key (on the back of the controller), turn on the controller. The blinking red light should become a solid/constant red light. This means that they have been binded/paired successfully.

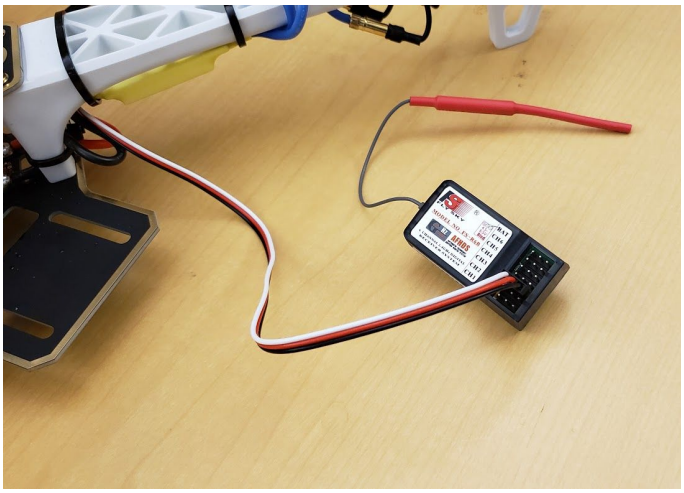
Step 10: Calibrating the ESCs

We need to calibrate the ESCs so that they are sensitive to the throttle input from the RC controller.

Components: RC controller, drone, RC receiver, charged drone battery

Process:

Pick 1 ESC. Take its signal wire (white-black-red) and plug it into channel 3 on the receiver. Just as below, the white wire should be closest to the label on the receiver.



MAKE SURE YOU HAVE NO PROPELLERS (PROPS) INSTALLED!

With the drone powered off, turn on the RC controller. Then, take its throttle stick all the way up (FULL Throttle). See image below:

Now, plug in the battery.

You will hear a DING-DING.

After hearing that, put the throttle down all the way to NO Throttle. You will hear DING-DING-DING.

That means that ESC has been calibrated. Now do this for the remaining 3 ESCs.

Step 11: Checking motor spin direction

PLEASE PLEASE PAY ATTENTION.

We are putting a single prop onto a motor to check if it is spinning correctly in the correct direction.

Recall we have two directions:
CW and CCW.
Red top motor spins CCW
Black top motor spins CW

Process: Connect the signal wire of 1 ESC to Channel 3 of receiver. Then plug in the battery of the drone. Then turn on the RC controller.

Now, SLIGHTLY push the throttle. SLIGHTLY. If you push it too much your drone might lift and cut you or something else. DO NOT GO FULL THROTTLE. YOU WILL CUT YOUR EYE(S).

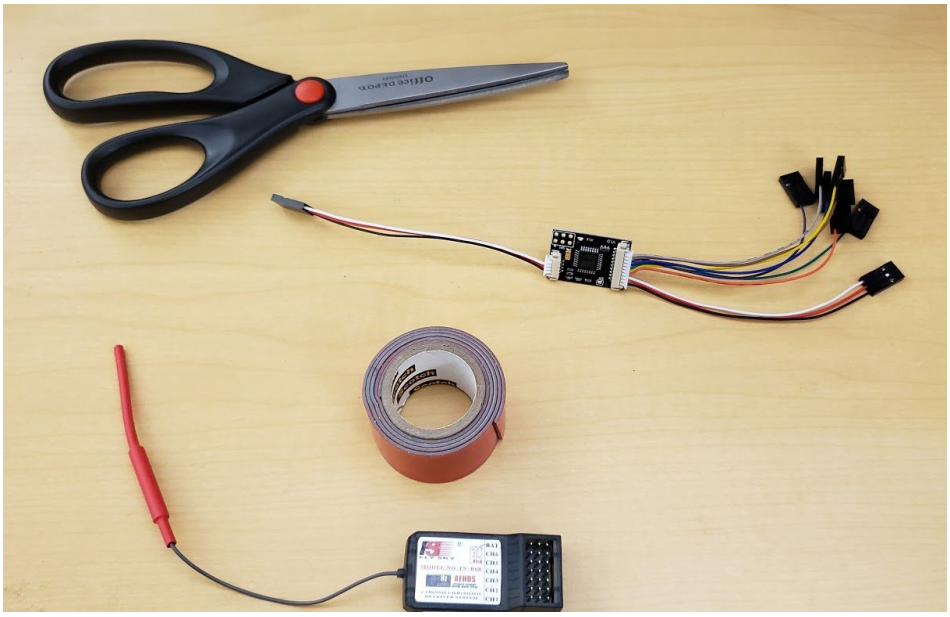
If the motor spins correctly, great! We can check the other motors.

If the motor doesn't spin correctly, swap 2 of the motor wire connections with the bullet connectors. This should fix it.

Check all motors.

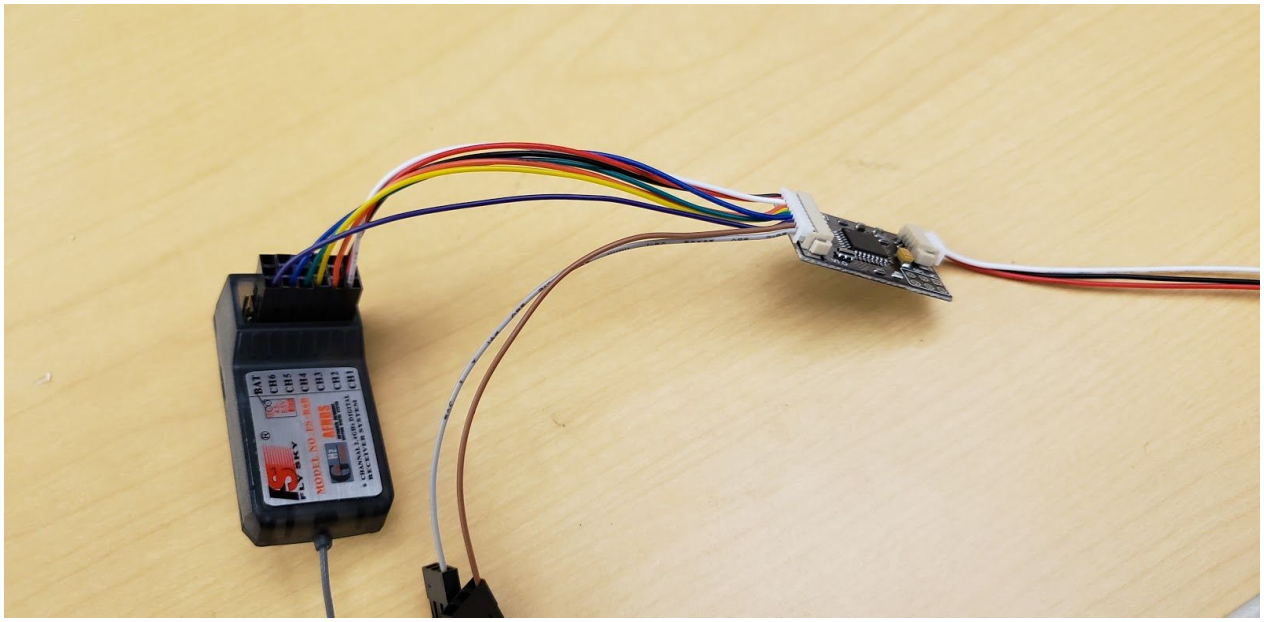
Step 12: Attach PPM encoder and RC receiver to the drone

Components: PPM Encoder and RC receiver, double-sided sticky tape

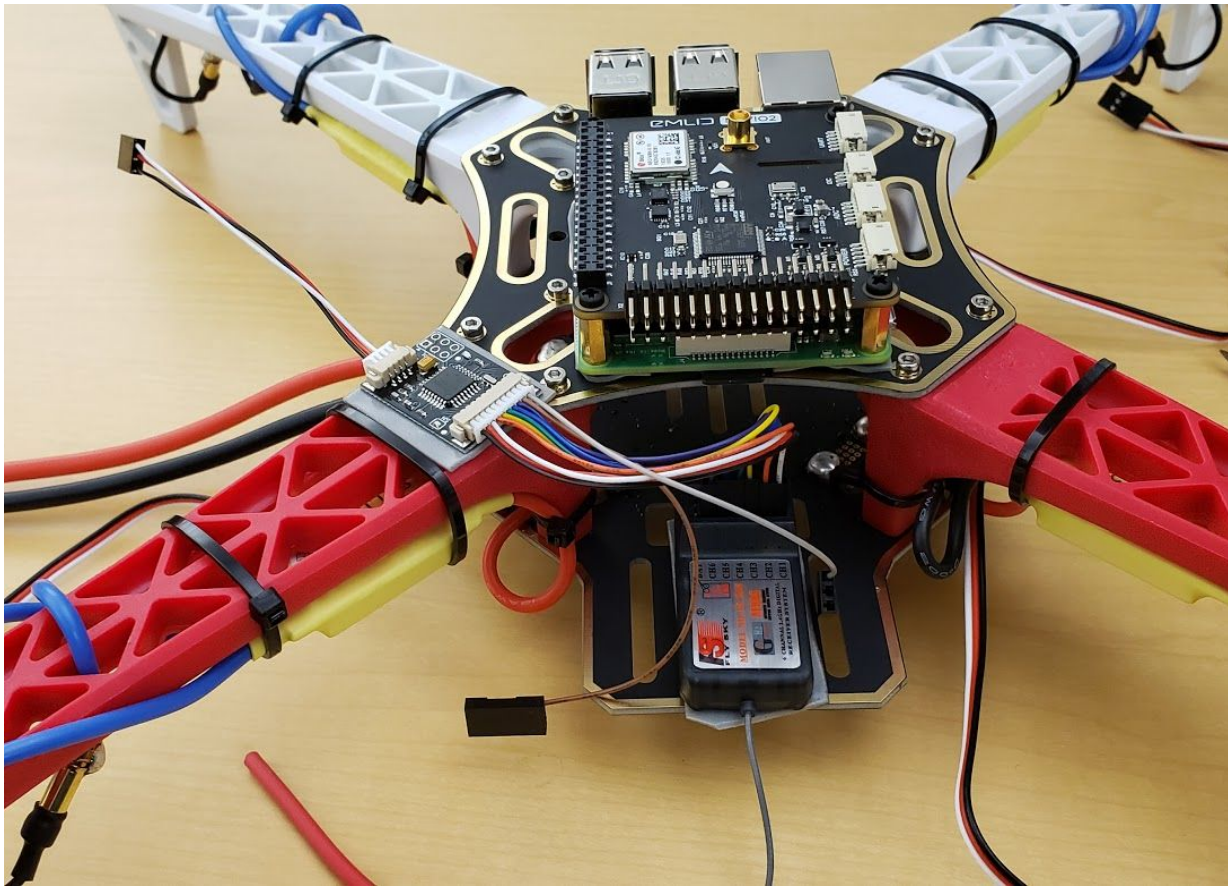


Process: First attach the wires to the PPM encoder if not already attached out of the box. Then follow the following configuration:

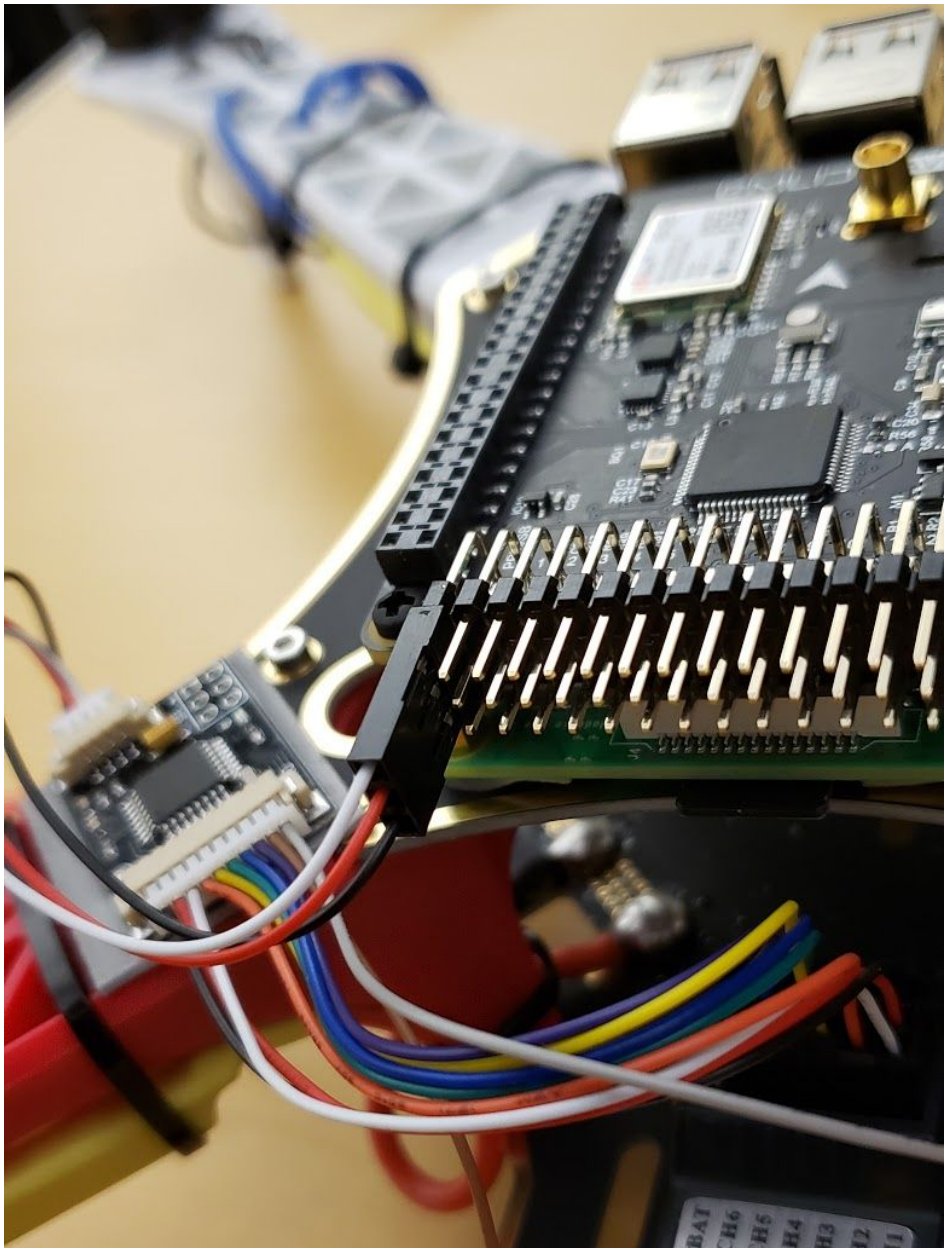
White-Red-Black wire into Channel 1 (White wire closest to label)
Orange wire into Channel 2 (closest to label)
Yellow wire into Channel 3 (closest to label)
Green wire into Channel 4 (closest to label)
Blue wire into Channel 5 (closest to label)
Purple wire into Channel 6 (closest to label)



Now, put tape on the underside of the PPM encoder and RC receiver and stick them onto the drone as shown below:

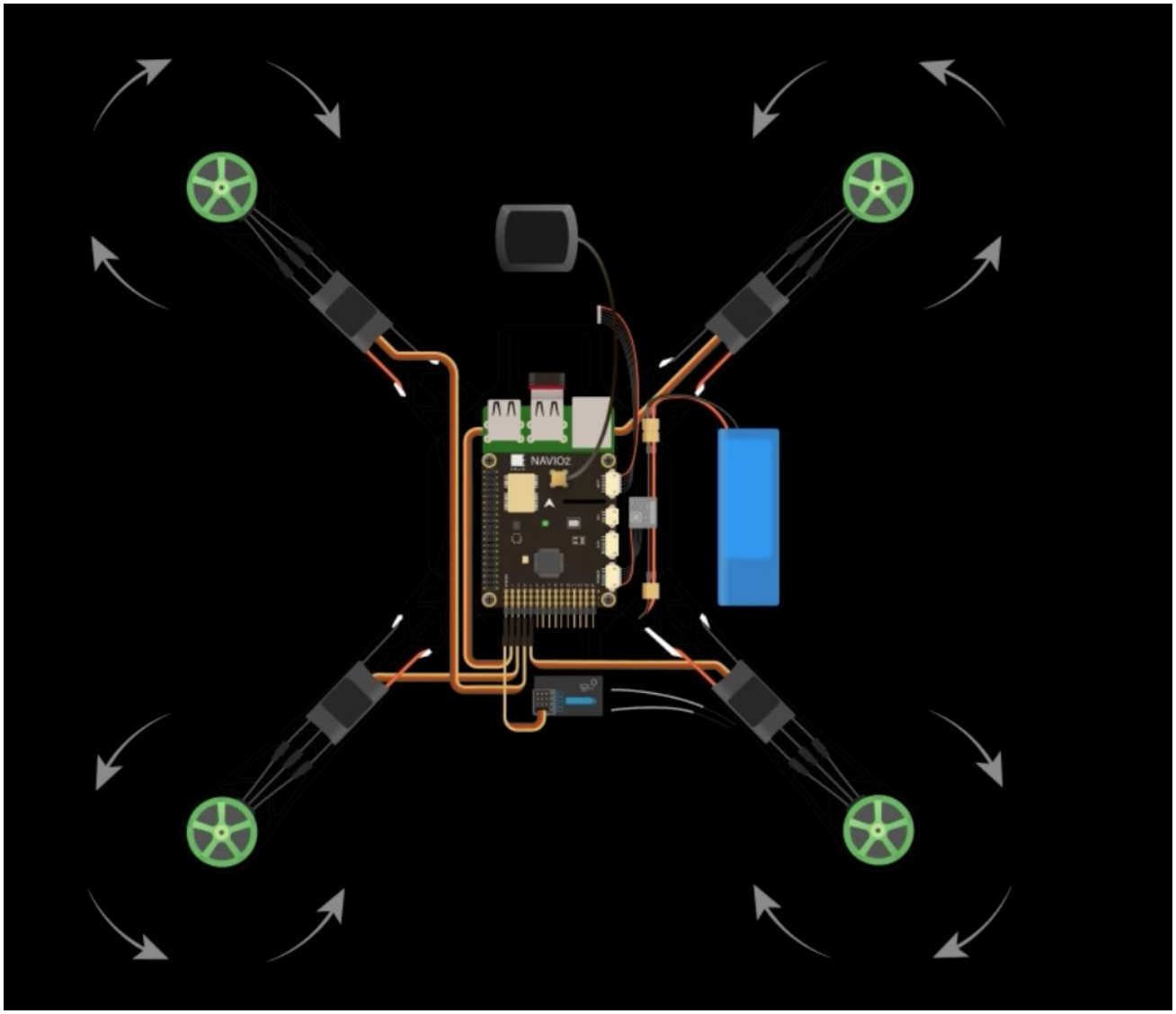


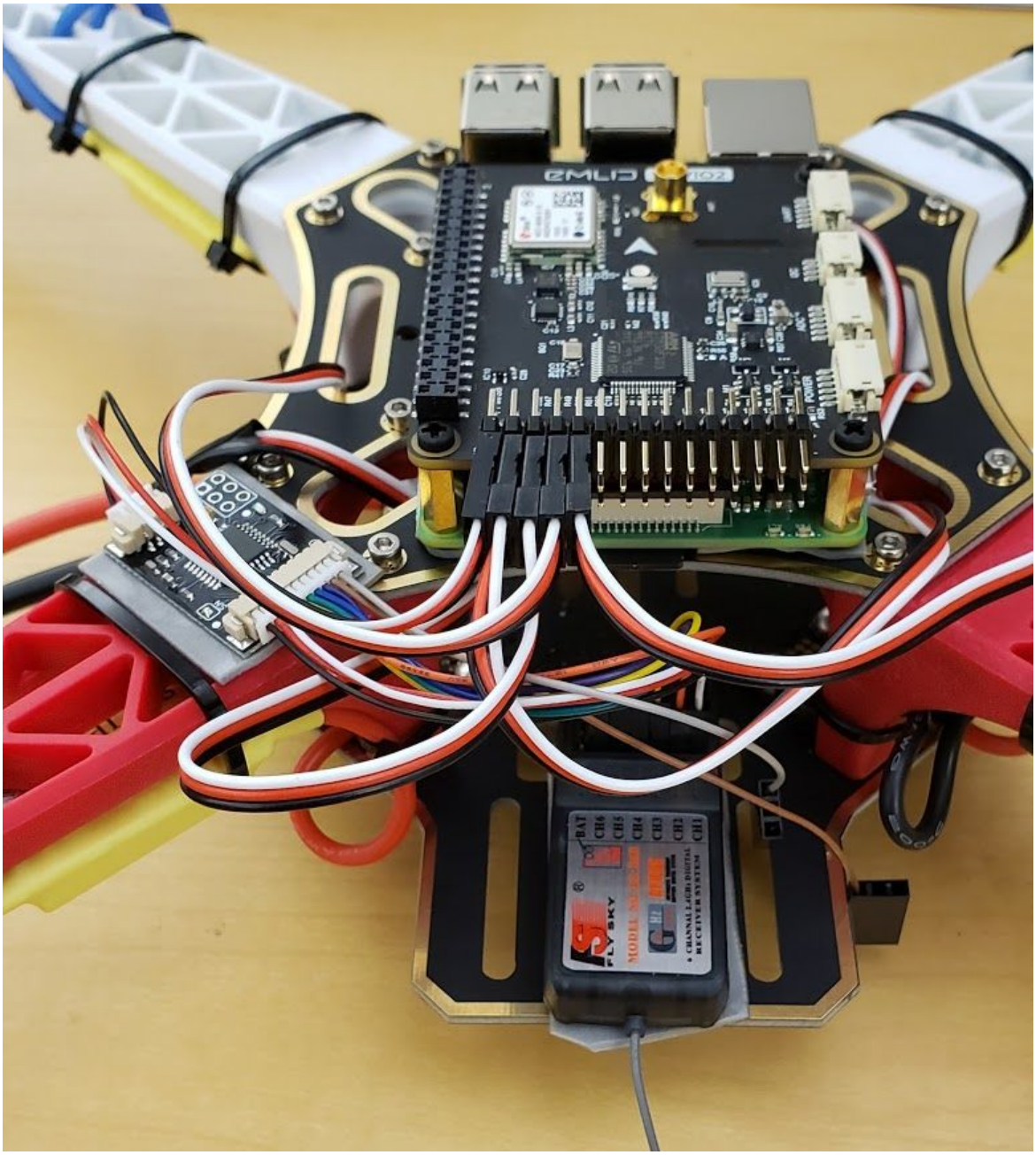
Take the output wire (white-red-black) and plug it into the PINS labeled PPM/SB on the NAVIO2.
The white wire should be on top. See image below:



Step 13: Connecting ESCs to the NAVIO2 HAT

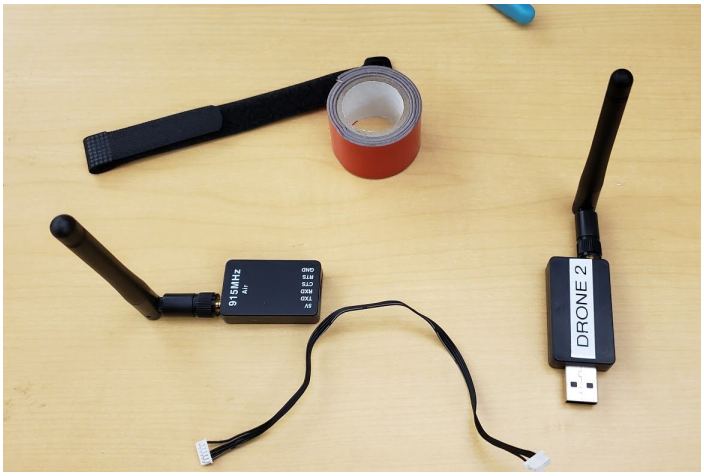
Process: This is the configuration to be used below. Plug in the ESC wires into the NAVIO2 hat. All the white wires should be on top.




FLYSKY

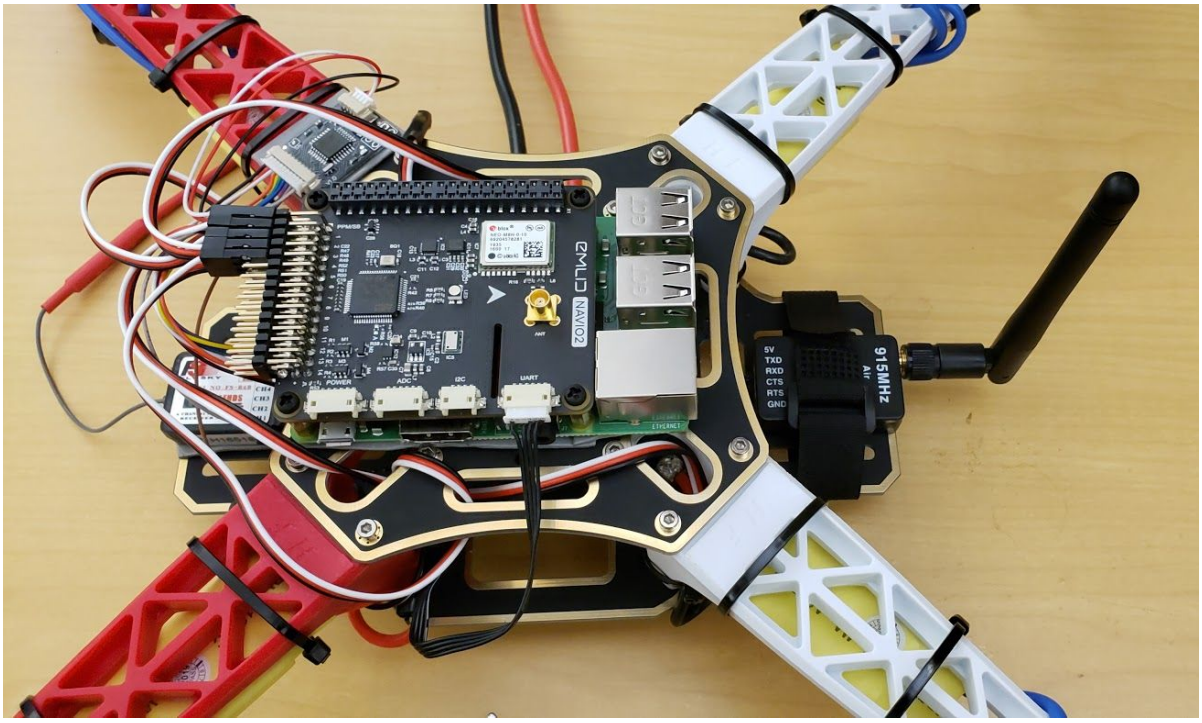
Step 14: Attaching and connecting the telemetry module to the drone

Components: 915MHz Ground and Air unit, 2 antennae, UART cable, velcro or sticky tape



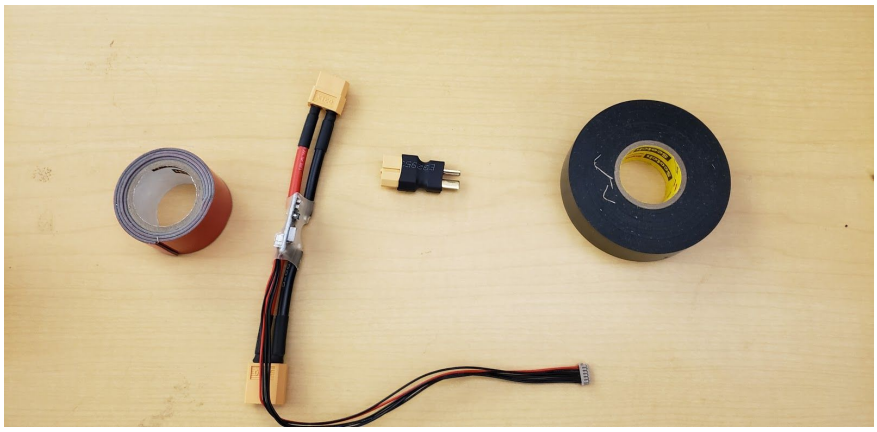
Process: First, screw on the antennae onto the modules. Then, put one end of the UART cable into the air module.

Now, attach the air module to the drone using either tape or a velcro strap. Then, take the output wire and attach it to the UART port on the NAVIO2 HAT.



Step 15: Attaching Power module to drone

Components needed: electrical tape, double sided tape, battery converter, and power module

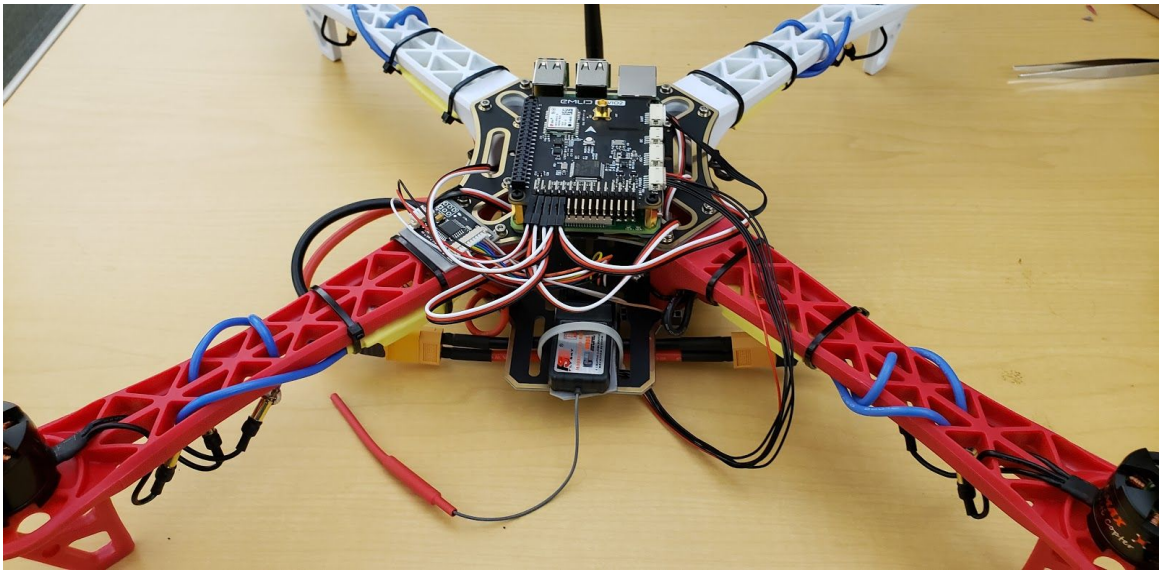


Process: First, cut the clear plastic on the power module.

Then, wrap the module in electrical tape.
Attach the battery converter to the module. It should only fit into one side of the module.

Put double sided tape on the power module. Stick the power module on the underside of the drone. Attach one terminal to the battery connector on the bottom plate of the drone. The direction of current is important!

Take the output power cables and attach them to the terminal labeled “POWER” on the NAVIO2 HAT.

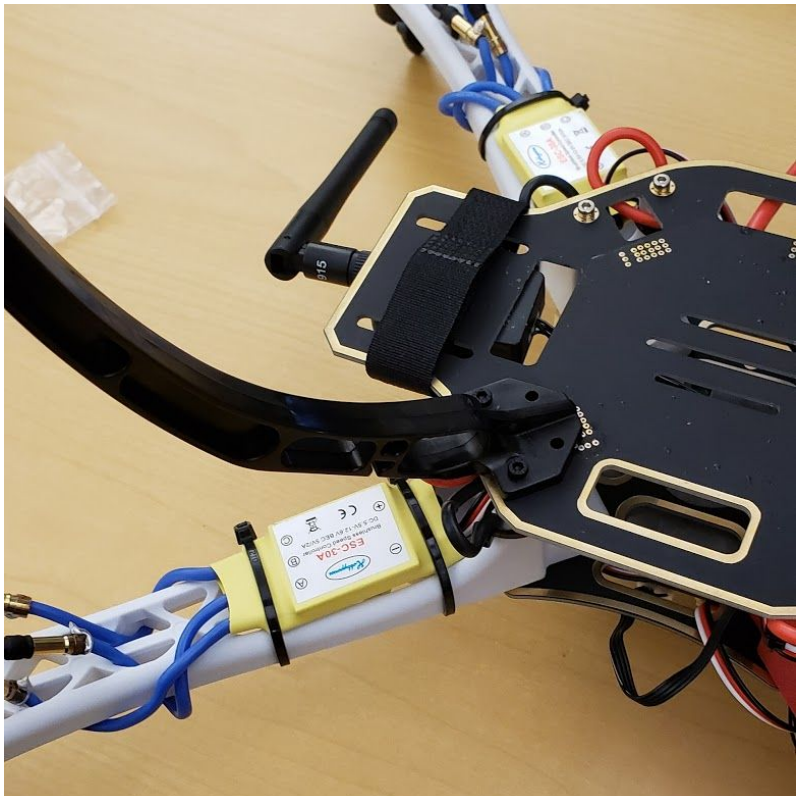


Step 15: Attaching landing gear (HIGHLY RECOMMEND)

Components needed: Black landing gear, black screws that come with landing gear, wrench

Process: Flip the drone over, remove the silver screws, and then store them. Using the black screws, attach the landing gear into the same screw holes.

In the end, it should look like this:



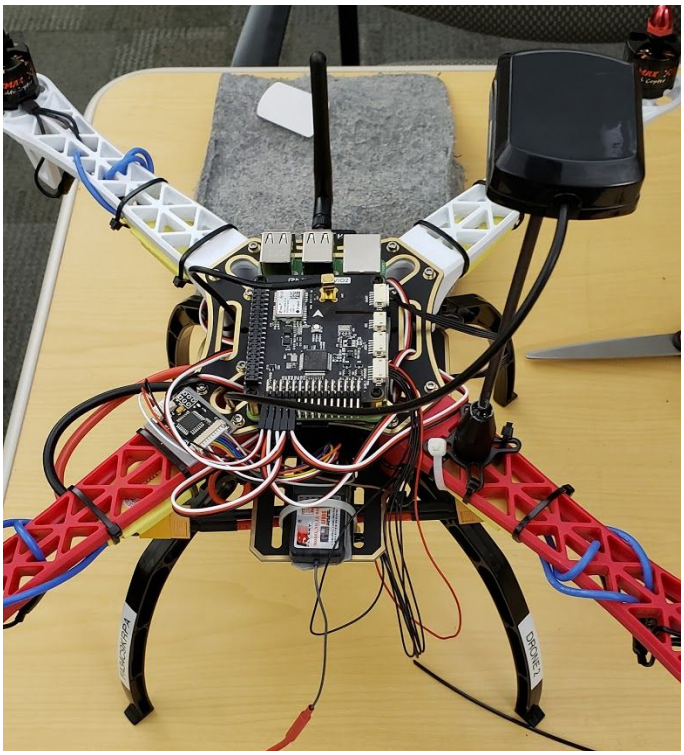
Repeat this on the other 3 landing gear legs.

Step 16: Building GPS mount and attaching GPS onto it

Components needed: GPS, GPS mounting hardware, wrench, superglue

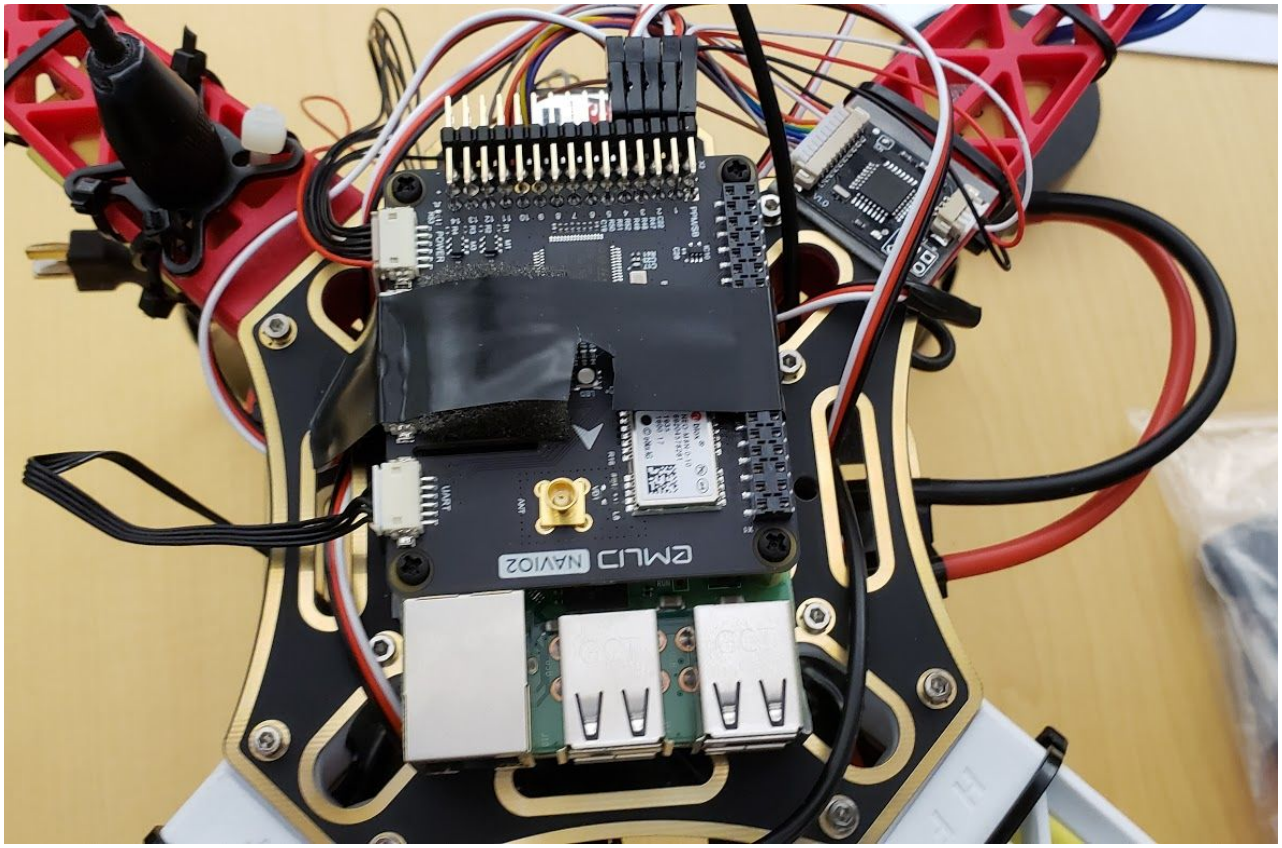
Process: using the wrench, tighten the screws. Then attach it to the drone.

Then, stick the GPS in the orientation shown below and connect the cable to the ANT port on the NAVIO2.



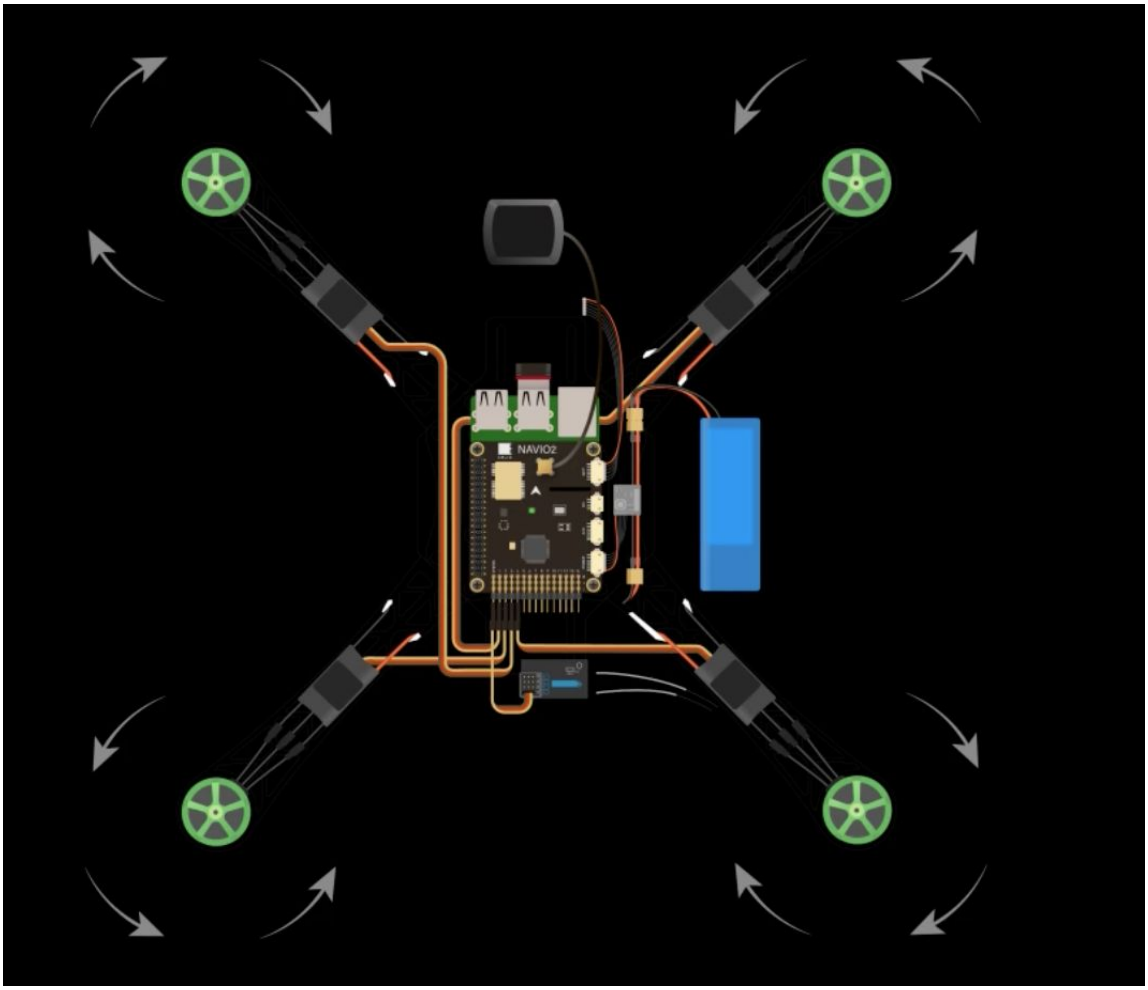
Step 17: Protecting the barometer from UV radiation (Very Important!)

Process: Using some thin foam and electrical tape, cover the barometer to protect it from UV radiation. See image below:



Step 18: Attach Props

Process: Using the same configuration shown below, attach the props.



Note: if you built the drone exactly like this guide, the red props will be on white arms and black props will be on red arms.

Step 19: Protect all electrical connections with electrical tape

Process: Cover all the ESC bullet connectors with electrical tape.

Step 20: Attach charged battery with velcro strap

Process: This step is up to user discretion. Attach the battery wherever you prefer using either velcro straps or some other secure method.

Drone Setup

Step 21: SSH to NAVIO2 to power source and run the emlidtool command shown

Process: Use the terminal and follow the steps.

SSH username is “pi”
SSH password is “raspberry”

Step 22: Familiarize yourself with arducopter

Process: Docs available at https://ardupilot.org/copter/